

## Abstract of the systematic review paper by Isabel Wilke: Biological and pathological effects of 2.45 GHz radiation on cells, fertility, brain, and behaviour (January 2018)

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### Subject Matter

The research draws attention to the need to reintroduce to policy-makers and the public debate the crucial matter of the effects of non-ionising radiation at the microwave frequency of 2.45 GHz and the health risks it might pose. The number of studies conducted and the significance of their findings still remains reversibly analogous to the measures taken to prevent its EMF/RF's detrimental effects. Insofar, numerous experiments have been carried out in cell cultures, humans, animals, bacteria, and plants.

### Methods of Analysis

More than 100 studies published in peer-reviewed journals were selected for analysis through the databases LIVIVO (ZBMED) and PubMed. The chosen studies were conducted by different research teams, aimed at different study objectives and focused on different exposure levels, addressing a broad spectrum of issues. No date limitation was applied.

### Key Findings

Regarding the impact on the *testes and sperm*, all 10 reviewed studies were consistent with the hypothesis of 2.45 GHz radiation implicating damage, thus compromising male fertility, while the testicular tissue was deemed more sensitive to DNA damage than other tissues. The findings include increased rates of testicular tissue degeneration that affects the quality, production and motility of sperm, and indicators of oxidative and/or nitrosative stress. Also, a drop on the levels of testosterone and melatonin was observed in the serum of the specimen. Tested separately, both melatonin intake, and exposure to pulsed electromagnetic fields of 100 Hz were able to reduce the effects of oxidative stress.

Out of the 8 reviewed studies on *female reproduction*, all of them reported adverse effects on the following: reproductive capacity (fecundity), pregnancy succession, and the impacts on the survival and development of the embryo. Additionally, young rats at developmental stages comparable to puberty in humans, displayed increased sensitivity to EMF radiation, and prenatally exposed offspring demonstrated altered behavioural responses and biochemical variables as adults.

Out of the *brain function and development (EEG) studies*, all 12 (plus 8 collectively referenced follow-up studies), report complications to the normal readings, but also depict a complex association between brain function/development and the effects of EMF/RF. To begin with, brain activity displayed alterations that were either catholic (brainwaves alpha, beta, delta, and theta), or differed gender-dependently, as in the cases of P300 waves, and the level of excitability of the cerebral cortex. Such alterations were attributed to impacts on the synchronization/desynchronization of firing neurons. Effects were also found in neurogenesis, the rostral migratory stream, long-term memory formation, spatial memory and spatial learning, microglia activation, in the water content of the brain, the glial cells prevalence, acetylcholine concentration, tissue changes (structural damage and inflammation in the brain), gene expression, and in oxidative damage in the brain.

Studies regarding *behavior* were conducted with regards to tracing changes in learning, memory, brain performance, typical behavioural patterns, and other responses, including anxiety and hyperactivity. Positive associations were made between the exposure to non-ionizing radiation and the negative outcomes. These include neuronal degeneration and the effects of decreased levels of creatine kinase and antioxidant enzymes in the brain, increased

levels of HSP70, apoptosis, ROS, RNS, lipid peroxidation, motor activity, protein damage, physiological changes in the hippocampus, changes involving neurotransmitter systems, decreased cholinergic activity in the frontal cortex, and DNA damage in brain cells.

**DNA damage**, mainly induced by oxidative stress was evident in 24 studies, in various cell samples (brain, blood, lymphocytes, testes, sperm), and less pronounced in others (skin, liver, kidneys). Such genotoxic and mutagenic effects, when frequently occurring may lead to neurodegenerative diseases, disorders, impairments of neurological functions, vascular damage in the brain tissue, neurasthenia, tumour promotion, mutations, apoptosis, and free radicals associated with various other diseases.

As regards to **carcinogenesis** promotion, the studies confirm the connection, identifying indirect pathways that involve oxidative processes, either through changes in enzyme activities, cell membrane properties (i.e. disturbance of the calcium homeostasis), or single- and double-strand DNA breaks, that lead to metabolic changes. Melatonin holds an important prophylactic role against cancer, due to its antioxidative and calcium channel regulative properties, however, nocturnal exposure to EMF radiation suppresses its secretion, thus diminishing its protective activity. Distance wise, studies on breast cancer confirmed the decreased level of risk at 10 cm distance from the source.

All of the 5 reviewed studies on **cardiac activity**, microcirculation, and the cardiovascular system as a whole concluded that the impact is significant, as it was established through physiological indicators (heart rate and blood pressure), biochemical parameters, cellular morphological abnormalities, findings of increased apoptosis rates in cardiac cells, and indicators signifying oxidative damage. The 10 Hz pulse included in Wi-Fi radiation was flagged as an additional detrimental factor on heart rate variability.

Out of the two reviewed studies regarding the **cell cycle**, both had their methods adjusted to rule out any changes owing to thermal effects. The results showed changes during all the stages of the cell cycle, and reversible changes in the mitotic spindle apparatus during cell division, resulting in increased apoptosis, after short-term radiation exposure of 15 minutes.

In the **liver**, oxidative stress was reportedly triggered, causing cellular and structural and ultrastructural tissue damage, including inflammation and necrosis, thus compromising its optimal functionality.

In studies on the **thyroid**, significant changes were determined on the levels of HSPs and thyroid hormones, the morphology of the thymus, and the responses of the animals. Effects on the thyroid and the thyroid hormones pose a risk to overall health through a variety of bodily functions, and on behaviour.

**Gene expression** alterations, were evident in the studies, indicating acute escalation of the effects, even after brief exposure. As of Lee et al. (2005), 221 genes were affected after 2 hours, and 896 after 6 hours, involving a range of proteins associated with apoptosis, metabolism, polysaccharide biosynthesis, RNA functions, RNA translation, transport and cell cycle. According to Yang et al. (2010; 2012), TNF- $\alpha$ , iNOS genes were altered, in addition to 41 stress-related genes in samples from the hippocampus.

In **cell membranes**, exposure dysregulates calcium ( $\text{Ca}^{2+}$ ) ion channels (i.e. VGCC and TRPM2), through polarization, even in extremely low exposure levels, due to its independency to power density levels. Particularly, the dysregulation of calcium homeostasis causes oxidative damage and affects functions such as cell growth, signal transmission, and apoptosis. Through the same mechanism, the increased  $\text{Ca}^{2+}$  influx into the cytoplasm was reported to cause increased cell growth in human leukemia cells.

The findings on the effects on **bacteria** raise concerns for possible health threat. Initially, exposure increases cell wall permeability, indirectly damaging bacterial cells. However, above a certain damage threshold, defense mechanisms become activated, granting them resistance to the effects of irradiation, and antibiotic resistance, even increasing their growth rates cell density in some species.

In *plants*, the effects were consistent with stress responses that could prove beneficial in agriculture, as by stimulating their antioxidant defence system, and causing anatomical adjustments, plants were able to better withstand salt stress, and increase their essential oils secretion rates (exposure to 900 GHz). The essential oil secretion was reduced compared to controls at Wi-Fi radiation (2.45 GHz).

## **Conclusions**

The report evaluates this range and concludes that based on the extensive body of research and the positive demonstration of adverse health and behavioral effects by the majority of the studies, it is recommended that ALARA measures are applied, especially for the protection of particularly vulnerable groups such as newborns, children and adolescents. Radiation of 2.45 GHz is a potent trigger of oxidative stress, that is the main source of implications, as was demonstrated, and can affect multiple organs and processes through large chemical chain reactions, either directly or indirectly. Various enforceable measures and compounds displayed protective efficacy against the effects of 2.45 MHz EMF/RF, yet the current official exposure limits do not correspond with research recommended limits.

## **Limitations of the Review Study**

The author highlights that while the examined studies confirm potential health impacts, the very limited amount of long-term and epidemiological studies, as well as studies on human subjects currently available disallows the disclosure of reliable figures.

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